Using RAGA for Multi-objective Planning of Soil and WaterConservation in a Small Watershed

Yankun Sun[1], Qiang Fu[2]

(1. School of Resources & Environment, Northeast Agriculture University,
Harbin, Heilongjiang 150030, China ;
2. School of Water Conservancy & Civil Engineering, Northeast Agriculture University,
Harbin, Heilongjiang 150030, China, fuqiang100@371.net)

Abstract: Difficulties of optimizing many parameters at the same time were overcome by combining the optimized method named Real coded based Accelerating Genetic Algorithm (RAGA) with multi-objective planning techniques. Both partial optimization and quick convergence could be achieved. A multi-objective planning model was used to suggest soil and water conservation measures for a small watershed named Xinglong in the Song Nen Plain. [Nature and Science, 2004,2(1):79-84].

Keywords: RAGA, small watershed, soil and water conservation, multi-objection planning, model

1 Introduction

At present, there are many methods that have been used in small watershed soil and water conservation comprehensive planning. For example, multi-objective planning, empirical planning, computer aided planning, linear programming and objective planning. Because linear programming has the shortcoming of single object, and objective planning desires there must have expected value in every objective function, multi-objective planning can overcome both shortcoming and satisfy the multi-objective demand in small watershed soil and water conservation comprehensive planning. So, multi-objective planning has been applied widely. (Zhou. 1997) Also method of step by step (STEM) is usually adopted to calculate the problem of multi-objective planning and essential of this method is a iteration method or trial method. Since there are many parameters and restrict factors, and the interior relations are complex. Though it is easy to converge and mature early. But, it is easy only to seek the partial best value, and can't seek the overall best value. For these reasons, the author put forward to combine the GA (Genetic Algorithm) with multi-objective planning to deal with this kind of issue. the Xinglong small watershed soil and water conservation comprehensive planning in Songnen Plain, and build up the multi-objective comprehensive planning model based on GA.

2 Real Coding Based Accelerating Genetic Algorithm (RAGA)

Genetic Algorithm has been put forward by Professor Holland. (Michigan University, USA) The main operations include selection, crossover and mutation. (Jin, *et al*. 2000; Fu, *et al*. 2001; Yun. 2000; Xuan, *et al*. 2000)

The coding mode of traditional GA adopted binary system. But binary system coding mode has many abuses. So, inheriting the work by Jin in 2000, the author put forward a new method named RAGA, which includes 8 steps. (Jin, *et al*. 2000; Fu, *et al*. 2001).

3 A Case Study

Xinglong small watershed lies in the middle part in Heilongjiang Province of China. It has been dig up in 1900. The main soil style is chernozem. The depth of soil is 30mm to 40mm.

The whole area of 843.12 hm^2 , that accounts for 66.7 percent of the watershed, has been eroded. The available soil depth is reducing in successive years. The soil fertility descends and the provision reduced. According to investigation, there are about 0.3 to 0.7 hm^2 sloping field have been nibbled. The soil and water loss is rather serious. So, it is necessary to carry through soil and water conservation comprehensive planning and set up synthetic optimum mode. Thus, we can advance the economy development of the watershed and prevent and cure the disaster of soil and water loss. (Zhou. 1997).

3.1 Select and treat with the objective function (Zhou. 1997; Yun, *et al*. 2000)

According to the natural economy rule and people's demand, we can define the objective function as follows.

(1) The maximum economy net income

$$Maxf_1(x) = 134.5x_1 + 97x_2 + 59.5x_3 + 491x_4 + 391x_5 + 291x_6 + 423x_7 + 363x_8 + 231x_9 + 155x_{10} + 135x_{11} + 650x_{12} + 600x_{13} + 329x_{16} + 329x_{17} + 329x_{18} + 852x_{25} + 17.5x_{26} + 22.5x_{27} + 72x_{28} + 210x_{29} + 160x_{30}$$

(2) The maximum provision yield

$$Maxf_2(x) = 350x_1 + 300x_2 + 250x_3 + 1200x_4 + 1000x_5 + 800x_6 + 400x_7 + 350x_8 + 240x_9 + 200x_{10} + 180x_{11}$$

(3) The minimum quantity of soil loss

$$M\inf_3(x) = 0.333(x_1 + x_4 + x_7) + 0.017x_2 + 0.036(x_3 + x_5) + 0.1313x_6 + 0.164x_8 + 0.134x_9 + 0.073(x_{10} + x_{12}) + 0.153(x_{11} + x_{13}) + 0.25(x_{16} + x_{17} + x_{18} + x_{19} + x_{20} + x_{21} + x_{22} + x_{23} + x_{24})$$

We can adopt the method of linearity-weighted array to transform multi-objective function to single objective function.

$$MaxF = \sum_{i=1}^{3} \alpha_i \cdot Maxf_i(x) = \alpha_1 \cdot Maxf_1(x) + \alpha_2 \cdot Maxf_2(x) + \alpha_3 \cdot M\inf_3(x)$$

According to the experience of experts, we select the weight coefficients are as follows:

① The coefficient of the maximum economy net income is 0.55 ($\alpha_1 = 0.55$);

② The coefficient of the maximum provision yield is 0.35 ($\alpha_2 = 0.35$);

③ The coefficient of the minimum quantity of soil loss is 0.1 ($\alpha_3 = 0.1$).

3.2 Make the decision-making variable and restraint condition (Zhou. 1997)

According to the practical condition, we setup variables that have great influence and drop out variables that have little influence. At last, we select the 30 decision-making variables as follows. See also table 1.

Table 1 Table of decision-making parameters

Decision-making variable	Meanings of decision-making variable	Decision-making variable	Meanings of decision-making variable	Decision-making variable	Meanings of decision-making variable
x_1	Area of the first grade field for planting wheat.	x_{11}	Area of the third grade field for planting mixed grain through building sloping terrace	x_{21}	Area of the fourth grade field to planting timber
x_2	Area of the second grade field for planting wheat through building terrace	x_{12}	Area of the second grade field for planting economy crop through building terrace	x_{22}	Area of the second grade field to planting shrub
x_3	Area of the third grade field for planting wheat through building sloping terrace.	x_{13}	Area of the third grade for planting economy crop through building sloping terrace.	x_{23}	Area of the third grade field to planting shrub
x_4	Area of the first grade field for planting corn.	x_{14}	Area of the second grade field for planting artificial grazing	x_{24}	Area of the fourth grade field to planting shrub
x_5	Area of the second grade field for planting corn through building terrace	x_{15}	Area of the third grade field to planting artificial grazing	x_{25}	Number of milch cow
x_6	Area of the third grade field for planting wheat through building sloping terrace.	x_{16}	Area of the second grade field to planting economy woods.	x_{26}	Number of chicken
x_7	Area of the first grade field for planting soybean.	x_{17}	Area of the third grade field for planting economy woods.	x_{27}	Number of duck and goose
x_8	Area of the second grade field for planting soybean through building terrace	x_{18}	Area of the fourth grade field for planting economy woods.	x_{28}	Number of sheep
x_9	Area of the third grade field for planting soybean through building sloping terrace.	x_{19}	Area of the second grade field for planting timber	x_{29}	Number of pig
x_{10}	Area of the second grade field for planting mixed grain through building terrace	x_{20}	Area of the third grade field for planting timber	x_{30}	Number of big livestock

We can construct four kinds of restricted function according to many aspects. Such as soil resources, population, grain and oil, farming, feedstuff, dry firewood, yield, fertilizer, labor, yield development, people's demand and so on.

3.2.1 Soil restriction

(1) The first grade land restriction:

$$x_1 + x_4 + x_7 = 6849.25$$

(2) The second grade land restriction:

$$x_2 + x_5 + x_8 + x_{10} + x_{12} + x_{14} + x_{16} + x_{19} + x_{22} = 5499.4$$

(3)The third grade field restriction.:

$$x_3 + x_6 + x_9 + x_{11} + x_{13} + x_{15} + x_{17} + x_{20} + x_{23} = 4625.11$$

(4)The fourth grade land restriction:.

$$x_{18} + x_{21} + x_{24} = 331.64$$

3.2.2 Production development restriction.

(5) In order to satisfy the demand of commodity grain base for provision, the average area can't be less than 0.37hm^2. The total population is 2094.

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} \geq 12000$$

(6) The area of artificial grassland can't be less than $100\ \text{hm}^2$. $x_{14} + x_{15} \geq 1500$

(7) The bestrow rate by forest should be more than 20 percent.

$$x_{16} + x_{17} + x_{18} + x_{19} + x_{20} + x_{21} + x_{22} + x_{23} + x_{24} \geq 2651.9$$

(8) According to the national task, the total output can't be less than 1700000 kg.

$$350x_1 + 300x_2 + 250x_3 \geq 1700000$$

(9) The yield of soybean can't be less than 200000 kg. $400x_7 + 350x_8 + 240x_9 \geq 400000$

(10) The demand for other food grains can't be less than 2.5 kg per people.

$$200x_{10} + 180x_{11} \geq 10470$$

(11) According to exploited standard of small watershed, the area of economy wood can't be less than 20 percent of wood.

$$x_{16} + x_{17} + x_{18} \geq 20\% \begin{pmatrix} x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} \\ + x_{20} + x_{21} + x_{22} + x_{23} + x_{24} \end{pmatrix}$$

(12) The capital construction restriction.

$$\begin{aligned} & x_2 + x_5 + x_8 + x_{10} + x_{12} + x_{14} + x_{15} + x_{22} + x_{23} + x_{24} + \\ & 8(x_3 + x_6 + x_9 + x_{11} + x_{13}) + 3(x_{16} + x_{17} + x_{18}) \\ & + 4(x_{19} + x_{20} + x_{21}) \leq 51128 \end{aligned}$$

3.2.3 Balancing restriction.

(13) Balance restriction of forage grass.

$$\begin{aligned} & 175x_1 + 140x_2 + 105x_3 + 245x_4 + 210x_5 + 175x_6 \\ & + 175x_7 + 140x_8 + 112x_9 + 140x_{10} + 122x_{11} \\ & + 3000x_{14} + 3000x_{15} - 5000x_{25} - 1300x_{28} \\ & - 1800x_{29} - 4400x_{30} \geq 96000 \end{aligned} \quad (14)$$

Balance restriction of forage firewood.

$$\begin{aligned} & 325x_1 + 260x_2 + 195x_3 + 455x_4 + 390x_5 + 325x_6 \\ & + 325x_7 + 260x_8 + 208x_9 + 260x_{10} + 223x_{11} \\ & + 600x_{22} + 600x_{23} + 540x_{24} + 160x_{19} + 160x_{20} \\ & + 150x_{21} \geq 2292930 \end{aligned} \quad (15)$$

Balance restriction of organic fertilizer.

$$\begin{aligned} & 2500(x_1 + x_2) + 1500(x_4 + x_5 + x_{10} + x_{11} + x_{12} + x_{13}) \\ & + 2000x_3 + 1400x_6 + 1300(x_7 + x_8 + x_9) \\ & + 80(x_{16} + x_{17} + x_{18}) - 21900x_{25} - 500x_{26} - 900x_{27} \\ & - 2000x_{28} - 14400x_{29} - 21600x_{30} \leq 8376000 \end{aligned}$$

(16) Balance restriction of provision.

$$\begin{aligned} & 350x_1 + 300x_2 + 250x_3 + 1200x_4 + 1000x_5 \\ & + 800x_6 + 400x_7 + 350x_8 + 240x_9 + 200x_{10} \\ & + 180x_{11} - 1000x_{25} - 60x_{26} - 80x_{27} - 30x_{28} \\ & - 500x_{29} - 900x_{30} \geq 3141000 \end{aligned}$$

3.2.4 Balance restriction of stockbreeding

(17) Sheep: $x_{28} = 470$;

(18) Pig: $x_{29} \leq 1410$;

(19) Big livestock: $x_{30} = 470$;

(20) Milch cow: $x_{25} \geq 250$;

(21) Chicken: $x_{26} \leq 2350$;

(22) Duck and goose: $x_{27} \leq 1410$;

(23) $x_i \geq 0 \quad (\text{i} = 1,2,\cdots 30)$.

3.3 Treat with the restricted function. (Jin, *et al*. 2000; Xuan, *et al*. 2000)

Because there are so many restricted conditions in the model, so, we should treat with the restricted conditions in order to ensure all the results are fit for every restricted condition. We can adopt the method of punished function. According to the method, we can add a punishment item in the objective function. Thus, we can obtain a generalized Thereby, we can seek the best value of the original issue based on the function of punishment item.

$$MaxF' = \alpha_1 \cdot Maxf_1(x) + \alpha_2 \cdot Maxf_2(x) + \alpha_3 \cdot M\inf_3(x) - \sum_{i=1}^{m} h_i(g_i(x))$$

$h_i(g_i(x))$ ——punish item.

When the restriction of $g_i(x)$ are satisfy the condition, the value of $g_i(x)$ equal zero, otherwise, give the $g_i(x)$ a big number M. (M=1000)

F' ——the optimum function

3.4 Seek the best parameters based on RAGA

Applying MATLAB 5.3 software, the author obtained the best value of these 30 parameters based on RAGA. During the course of RAGA, the parent generation scale is 400. ($n = 400$) The crossover probability is 0.80. (p_c =0.80) The mutation probability is 0.80. (p_m =0.80) The number of excellence individual is 20. α =0.05. Through accelerating 30 times, we can obtain the best project value. See also table 2.

Table 2 Optimizing the parameters based on RAGA

Variable	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Optimum value (project 1)	3650.8	690.8	981.7	2261.3	832.7	672.2	937.1	741.9	571.1	376.5
Optimum value (project 2)	2643.4	710.6	754.2	3392.3	812.1	675.2	813.6	616.2	774.7	367.7
Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}
Optimum value (project 1)	517	608.9	269.6	682	837.5	668.3	291.7	107.1	292.7	262.1
Optimum value (project 2)	569.3	690.4	259.5	929.9	639.3	913.8	403.4	111.1	315.4	244.1
Variable	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}	x_{26}	x_{27}	x_{28}	x_{29}	x_{30}
Optimum value (project 1)	95.9	605.5	222.1	128.6	392.5	977.6	329.7	470	1085.2	470
Optimum value (project 2)	110.8	143.3	305.4	109.7	460.5	1003.7	636.9	470	1015.3	470
Optimum value (project 1)	$MaxF' = 4.939\times10^6$ $Maxf_1(x) = 4.6823\times10^6$ Yuan $Maxf_2(x) = 6.7545\times10^6$ kg $Maxf_3(x) = 3.5051\times10^3$ t									
Optimum value (project 2)	$MaxF' = 5.548\times10^6$ $Maxf_1(x) = 5.2178\times10^6$ Yuan $Maxf_2(x) = 7.653\times10^6$ kg $Maxf_3(x) = 3.5111\times10^3$ t									

3.5 Analyze the optimum result

When the above 23 restricted conditions have been satisfied, the best result of net income is 4682300 Yuan, the total yield is 6754500 kg, the soil and water loss is 3505.1t. At the same time, the soil utility is much more reasonable. The soil used by agriculture reduces from 77.38% to 69.15. The original positive slope cultivation has been changed to transverse slope cultivation. Furthermore, sloping terrace and terrace have been build. Thus, we can combine the utilization soil with soil protection. The area of forestry changes from 6.01% to 14.1%. The bestrow rate by forest increases obviously. The environment has been improved. The layout of building economy wood and shrubbery is in reason and play a part. The system of soil and water conservation forest can control the soil and water loss effectively. The soil resources in the watershed have been developed greatly. The area of stockbreeding increases from 0.63% to 8%. The quality of grassland field has been improved, and the number of livestock increases much, the people's income increases obviously. The average income is 2236.1 Yuan (Three times than 700.4 Yuan before planning.), and the provision is 3225.6kg. (2.71 times than 1190.4kg before planning.) The erosion degree lighten, the covered rate enhance, the disaster of flood and waterlog lighten. The zoology benefit is good. After planning, the covered rate can reach 26.58%.

The soil distribution sees to table 3.

3.6 Discussion

If we adjust a part of restricted conditions properly, the total benefit will reach the better value. For example, if we reduce the demand of wheat, and increase the planting area of other crop (corn, soybean and economy crop.), the total benefit will much well.

$$350\,x_1 + 300\,x_2 + 250\,x_3 \geq 1300000$$

The optimum result sees to table 2. The soil distribution of every way sees to table 3 and figure 1.

From table 1 we can see that the total benefit enhance after adjusting the planting rate. The area of wheat reduces the area of corn, soybean and economy crop increase. That means the net income and total yield increase much, the quantity of soil loss varied a little. It is obvious that the project 1 is better than project 2 under the

Table 3 Soil distribution for each way

Item	Before adjustment.		Adjust project 1.		Adjust project 2.		Source of increasing field and reducing field
	Area before adjustment （hm^2）	Account for the total area. （%）	Area after adjustment （hm^2）	Account for the total area. （%）	Area after adjustment （hm^2）	Account for the total area. （%）	
Agriculture	14671.6	77.38	13111.6	69.15	13079.2	68.98	Forestry, stockbreeding, Garden.
Forestry	1140.1	6.01	2674	14.1	2657	14.01	Agriculture, wasteland
Stockbreeding	120	0.63	1519.5	8.0	1569.2	8.28	Agriculture, wasteland
Garden	0	0	850	4.48	850	4.48	Agriculture, wasteland
Wasteland	2873.8	15.16	654.4	3.45	650.1	3.43	Forestry, stockbreeding, garden, agriculture
Others	154.5	0.82	154.5	0.82	154.5	0.82	

condition of satisfying the provision supply. In fact, we can adjust any other some restricted conditions properly according to the concrete demand, then the total benefit will reach the best.

4 Conclusion

(1) The author improves the standard genetic arithmetic (SGA) and adopts the real code. Through reducing the region of the excellent individual step by step, the author puts forward a new method named RAGA. The method of RAGA can overcome many shortcomings in SGA. Furthermore, the author applies the RAGA to the model of multi-objective planning. The result is satisfactory.

(2) The author adopts the method of linearity weighted and builds the objective function. The issue of multi-objective function has been changed to single objective function. At the same time, through adopting the punish function, the author treats with many restricted conditions. The best result will be calculated under the condition of satisfying all the restricted conditions.

(3) The author builds up the model of multi-objective comprehensive planning of Xinglong small watershed in Songnen Plain based on RAGA. The result indicates the total benefit would reach much better if we adjusted some restricted conditions. Such as we can make the area rate of agriculture, forestry and stockbreeding from 77.38:6.01:0.63 to the rate in project 1 (69.15：14.1：8.00) or project 2 (68.98：14.01：8.28). Thus, the environment will be improved, soil and water loss will be prevented and cured effectively, the people’s living standing will be enhanced.

(4) If we only adjusted the planting rate properly, the net income and total yield would increase obviously, and the quantity of soil loss would vary little. But the total benefit would be much better.

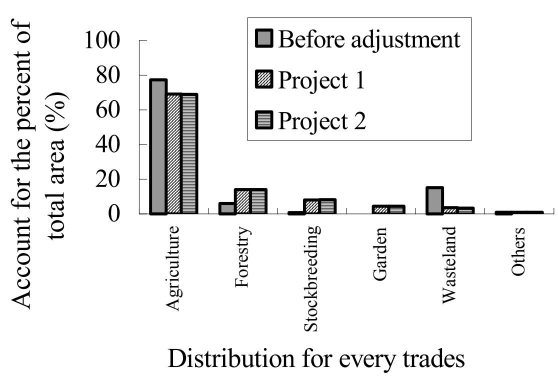

Fig.1 Soil distribution for each way between original and adjusted

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